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Description

Tuned Perturbation Cone Feed for Reflector Antenna

BACKGROUND OF INVENTION

[0001] Field of the Invention

[0002] This invention relates to microwave dual reflector antennas typically used in terrestrial point to point, and point to multipoint applications. More particularly, the invention provides a low cost self supported feed solution for use in frequency bands between 5GHz and 60GHz wherein stringent regulatory standard compliance and or specific system electrical characteristics are required. The invention is particularly suited to "deep dish" designs overcoming performance limitations of prior art devices and obviating the need for a conventional shroud assembly. It is also applicable to more conventional dish profiles.

[0003] Description of Related Art

[0004] Dual reflector antennas employing self-supported feed

direct a signal incident on the main reflector onto a sub-reflector mounted adjacent to the focal region of the main reflector, which in turn directs the signal into a waveguide transmission line typically via a feed horn or aperture to the first stage of a receiver. When the dual reflector antenna is used to transmit a signal, the signals travel from the last stage of the transmitter system, via the waveguide, to the feed aperture, sub-reflector, and main reflector to free space.

[0005] Dual reflector antennas utilizing a sub-reflector supported and fed by a waveguide are relatively cost efficient. This configuration also facilitates the mounting of an "Outdoor Unit" comprising the initial stages of a transceiver system, directly onto the back of the main reflector and also eliminates the need for a separate feed support structure that would conventionally span the face of the main reflector, thereby introducing some loss in operating efficiency. The waveguide can have either a rectangular cross-section, whereby the antenna is single polarized, or can have a square or circular cross-section facilitating dual-polarization operation.

[0006] The electrical performance of an antenna used in terrestrial communications is characterized by its gain, radiation

pattern, cross-polarization and return loss performance efficient gain, radiation pattern and cross-polarization characteristics are essential for efficient microwave link planning and coordination, whilst a good return loss is necessary for efficient radio operation.

[0007] These principal characteristics are determined by a feed system designed in conjunction with the main reflector profile. Conventional antenna designs used extensively in terrestrial point to point communications utilize a parabolic main reflector together with either a "J-hook" type waveguide feed system, or a self supported sub-reflector type feed system. In order to achieve "high performance" radiation pattern characteristics, these designs typically use an RF energy absorber lined cylindrical shroud around the outer edge of the main reflector antenna in order to improve the radiation pattern particularly in directions from approximately 50 to 180 degrees from the forward on axis direction. Shrouds however increase the overall weight, wind load, structural support and manufacturing costs of the antenna.

[0008] An alternative method to improve the radiation pattern in these angular regions is to use a "deep" dish reflector, i.e. the ratio of the reflector focal length (F) to reflector diam-

eter (D) is made less than or equal to 0.25 (as opposed to an F/D of 0.35 typically found in more conventional dish designs). Such designs can achieve "high performance" radiation pattern characteristics without the need for a separate shroud assembly when used with a carefully designed feed system which provides controlled dish illumination, particularly toward the edge of the dish. One such design which uses corrugations proximate to the outer radius of the sub-reflector to inhibit surface propagation and or field diffraction around the outer edge of the sub-reflector is described in US patent 5,959,590 issued September 28, 1999 to Sandford et al.

[0009] In dual-reflector feeds employing dielectric cone supported sub-reflectors, adequate feed radiation pattern characteristics may be designed for conventional (F/D>0.25) reflectors using simple unperturbed conic surfaces. Such a design presents a requirement for the feed to efficiently illuminate the main reflector over a total subtended angle of typically 130 degrees. Figure 1a illustrates one such design. Figures 1b and 1c show models of the typical resulting amplitude and phase feed radiation patterns of this configuration.

[0010] In order to provide the larger angular illumination for a

"deep dish" reflector (subtended angle >180 degrees), such a simple design is limited by internal and multi-path reflections prevalent within the cone structure between the rear reflecting surface and the leading edge boundary resulting in poorly controlled amplitude and phase radiation patterns with deep nulls at some frequencies within a typical operating band. Figure 2a illustrates one such design. Figures 2b and 2c show typical models of the resulting amplitude and phase feed radiation patterns for this configuration.

[0011] Multiple internal reflections can be reduced by the use of a regular array of corrugations positioned on the leading edge (cone surface closest to the main reflector). Figure 3a illustrates one such design. Figures 3b and 3c show typical models of the resulting amplitude and phase feed radiation patterns of this configuration, as described in European Patent Application 0 439 800 A1 by Kuhne filed December 1990. Such a configuration improves the impedance match between the cone medium and that of free space, thus presenting a less severe impedance boundary to the RF signal path. However such a configuration only partially resolves the internal reflections and can have a detrimental effect on both amplitude and

phase radiation match between E and H planes.

[0012] Therefore it is the object of the invention to provide an apparatus that overcomes limitations in the prior art, and in so doing present a solution that allows such a feed design to provide reflector antenna characteristics which meet the most stringent electrical specifications over the entire operating band used for a typical terrestrial communication microwave link.

Brief Description of Drawings

[0013] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the invention.

[0014] Figure 1a, is a partial schematic side cross-section view of a prior art embodiment of a dielectric cone supported sub-reflector used, for example, in conventional dual reflector antennas using shallow dish reflectors.

[0015] Figure 1b is a model of a typical amplitude feed radiation pattern for an antenna with the sub-reflector configuration of Figure 1a.

[0016] Figure 1c is a model of a typical phase feed radiation pat-

tern for an antenna with the sub-reflector configuration of Figure 1a.

[0017] Figure 2a is a partial schematic side cross-section view of a prior art embodiment of a dielectric cone supported sub-reflector cone body used in conventional dual reflector antennas using deep dish main reflectors.

[0018] Figure 2b is a model of a typical amplitude feed radiation pattern for an antenna with the sub-reflector configuration of Figure 2a.

[0019] Figure 2c is a model of a typical phase feed radiation pattern for an antenna with the sub-reflector configuration of Figure 2a.

[0020] Figure 3a is a partial schematic side cross-section view of a prior art embodiment of a dielectric cone supported sub-reflector as disclosed for example by the Kuhne reference, above.

[0021] Figure 3b is a model of a typical amplitude feed radiation pattern for an antenna with the sub-reflector configuration of Figure 3a.

[0022] Figure 3c is a model of a typical phase feed radiation pattern for an antenna with the sub-reflector configuration of Figure 3a.

[0023] Figure 4a is a cut-away side view of a deep dish dual re-

flector antenna with a self supported feed assembly with a tuned perturbation cone feed sub-reflector according to one embodiment of the invention.

[0024] Figure 4b is an angled front isometric view of the antenna shown in Figure 4a.

[0025] Figure 5a is an angled external lower side isometric view of a dielectric cone supported sub-reflector according to a first embodiment of the invention.

[0026] Figure 5b is an angled external upper side isometric view of the dielectric cone supported sub-reflector shown in Figure 5a.

[0027] Figure 5c is an external side view of the dielectric cone supported subreflector shown in Figure 5a.

[0028] Figure 5d is a top view of the dielectric cone supported sub-reflector shown in Figure 5a.

[0029] Figure 5e is a cut-away side view along the section line A-A of figure 5d.

[0030] Figure 6a is a chart of measured 22GHz E-plane co-polar radiation patterns achieved using the sub-reflector of Figures 5a-e within a 1" diameter shaped deep dish main-reflector, compared to ETSI E-plane and FCC regulatory radiation pattern specifications.

[0031] Figure 6b is a chart of measured 22GHz H -plane co-polar

radiation patterns achieved using the sub-reflector of Figures 5a-e within a 1" diameter shaped deep dish main-reflector, compared to ETSI E-plane and FCC regulation pattern specifications.

[0032] Figure 7 is a chart of measured and modeled return loss for the embodiment shown in Figures 5a-e.

[0033] Figure 8a is an angled external lower side isometric view of a dielectric cone supported sub-reflector according to a second embodiment of the invention.

[0034] Figure 8b is an angled external upper side isometric view of the dielectric cone supported sub-reflector shown in Figure 8a.

[0035] Figure 8c is an external side view of the dielectric cone supported subreflector shown in Figure 8a.

[0036] Figure 8d is a top view of the dielectric cone supported sub-reflector shown in Figure 8a.

[0037] Figure 8e is a cut-away side view along the section line A-A of figure 8d.

[0038] Figure 9a is a chart of measured 22GHz E-plane co-polar radiation patterns achieved using the sub-reflector of Figures 5a-e within a 1" diameter shaped deep dish main-reflector, compared to ETSI E-plane and FCC regulation pattern specifications.

[0039] Figure 9b is a chart of measured 22GHz H -plane co-polar radiation patterns achieved using the sub-reflector of Figures 5a-e within a 1" diameter shaped deep dish main-reflector, compared to ETSI E-plane and FCC regulation pattern specifications.

[0040] Figure 10a is a partial schematic side cross-section view of a third embodiment of a dielectric cone supported sub-reflector cone body according to the invention.

[0041] Figure 10b is a model of a typical amplitude feed radiation pattern for the antenna with the sub-reflector configuration of Figure 10a.

[0042] Figure 10c is a model of a typical phase feed radiation pattern for the antenna with the sub-reflector configuration of Figure 10aFigure 11a is a partial schematic side cross-section view of a fourth embodiment of a dielectric cone supported sub-reflector cone body according to the invention.

[0043] Figure 11a is a partial schematic side cross-section view of a fourth embodiment of a dielectric cone supported sub-reflector cone body according to the invention.

[0044] Figure 11b is a model of a typical amplitude feed radiation pattern for the antenna with the sub-reflector configuration of Figure 11a.

[0045] Figure 11c is a model of a typical representative phase feed radiation pattern for the antenna with the sub-reflector configuration of Figure 11aFigure 12a is a partial schematic side cross-section view of a fifth embodiment of a dielectric cone supported sub-reflector, having radial chokes (corrugations), according to the invention.

[0046] Figure 12a is a partial schematic side cross-section view of a fifth embodiment of a dielectric cone supported sub-reflector cone body, having radial chokes (corrugations), according to the invention.

[0047] Figure 12b is a model of a typical amplitude feed radiation pattern for an antenna with the sub-reflector configuration of Figure 12a.

[0048] Figure 12c is a model of a typical phase feed radiation pattern for the antenna with the sub-reflector configuration of Figure 12a Figure 13a is a partial schematic cross section view of a sixth embodiment of a dielectric cone supported sub-reflector configured to provide un-equal E and H-plane primary patterns.

[0049] Figure 13a is a partial schematic side cross-section view of a sixth embodiment of a dielectric cone supported sub-reflector configured to provide un-equal E and H-plane primary patterns, according to the invention.

[0050] Figure 13b is a model of a typical amplitude feed radiation pattern for the antenna of Figure 13a.

[0051] Figure 13c is a model of a typical phase feed radiation pattern for the antenna of Figure 13aFigure 13d is a chart of measured 38GHz E -plane co-polar radiation patterns achieved using the sub-reflector of Figure 13a within a 1" diameter shaped main-reflector, compared to ETSI and FCC radiation pattern specifications.

[0052] Figure 13e is a chart of measured 38GHz H -plane co-polar radiation patterns achieved using the sub-reflector of Figure 13a within a 1" diameter shaped main-reflector, compared to ETSI and FCC radiation pattern specifications.

Detailed Description

[0053] The self-supported feed system described herein integrates the waveguide transmission line, aperture and sub-reflector into a single assembly comprising a length of waveguide, the aperture of which is terminated with a corrugated dielectric cone sub reflector assembly, the front and back surfaces of which are geometrically shaped and corrugated to provide a desired amplitude and phase radiation pattern suitable for efficient illumination of the main reflector profile.

[0054] A typical dual reflector antenna according to the invention is shown in Figures 4a and 4b. The sub-reflector assembly 1 is mounted on and supported by a waveguide 2 to position the sub-reflector assembly 1 proximate a focal point of the dish reflector 3, here shown as a dish reflector 3 having a "deep dish" configuration.

[0055] Details of the sub-reflector 1 assembly according to the invention will now be described in detail. A first embodiment of a sub-reflector 1 according to the invention is shown in figures 5a-e. Representative and measured performance of the first embodiment is shown in Figures 6a-7. Further embodiments and their respective representative and or measured performance is shown in Figures 8a-13e. The sub-reflector assembly 1 may be formed, for example, by injection molding and or machining a block of dielectric plastic. A sub-reflector surface 5 of the sub-reflector assembly 1 may be formed by applying a metallic deposition, film, sheet or other RF reflective coating 10 to the top surface of the dielectric block. A waveguide junction portion 15 of the sub-reflector assembly 1 is adapted to match a desired circular waveguide 2 internal diameter so that the sub-reflector assembly 1 may be fitted into and retained by the waveguide 2 that

supports the sub-reflector assembly 1 within the dish reflector 3 of the reflector antenna proximate a focal point of the dish reflector 3.

[0056] One or more step(s) 20 at the end of the waveguide junction portion 10 and or one or more groove(s) 25 may be used for impedance matching purposes between the waveguide 2 and the dielectric material of the sub-reflector assembly 1.

[0057] The sub-reflector surface 5 and a leading cone surface 30 (facing the dish reflector 3) of the sub-reflector assembly 1 may have a plurality of concentric non-periodic perturbation(s) 35 in the form of corrugations, ridges and protrusions of varied heights, depths and or widths. Internal, external and combinations of internal and external perturbations may be applied. Also, a leading angle selected for pattern and VSWR matching between the waveguide junction portion 15 and a first perturbation, along the leading cone surface 30, may then change as the leading cone surface 5 continues to a periphery of the sub-reflector assembly 1, for example as shown on figure 13a. Where the prior art may have utilized a single perturbation for VSWR matching purposes, the present invention utilizes multiple perturbations to control internal reflections

and thereby form a desired radiation pattern. Calculated using a full wave solution with the assistance of commercially available full wave RF radiation pattern calculation software rather than ray tracing, the location and specific dimensions of the perturbations and angle changes may be calculated and then further iteratively adjusted to minimize multi-path reflections within the dielectric material, control amplitude and phase distribution from the feed and improve the impedance match (VSWR) between the feed and free space.

[0058] Further, as shown for example by Figures 13a-e, contrary to common practice requiring manipulation of the waveguide entry dimensions, where electrical requirements are non-equivalent between the vertical and horizontal (E and H-plane, or Etheta and Ephi) polarizations, for example for the 38 GHz band (ETSI EN 300833 Class 5 Figure 3C), the ridges height and width separately affect the different polarizations, at different frequency bands, even though the perturbation(s) 35 are concentric.

[0059] Because the perturbation(s) 35 are concentric, the sub-reflector assembly 1 need not be keyed to a specific orientation with the waveguide or reflector antenna. Also, machining of perturbation(s) 35 that would be difficult to

form by injection molding, alone, is simplified if a concentric design is selected.

[0060] Adapting the perturbation(s) 35 to a desired configuration provides efficiencies that previously were obtained in part by correcting the profile of the dish reflector 3. When these adaptations are made via the perturbation(s) 35, the invention provides the advantage of higher performance over a wide frequency range, for example 10-60 GHz, with the same reflector dish profile.

[0061] The combination of a "deep" phase corrected reflector with a sub-reflector assembly 1 according to the invention results in a reflector antenna operable over a wide frequency range with electrical characteristics previously available only with shallow profile reflector dishes with RF absorbing shrouds.

[0062] From the foregoing, it will be apparent that the present invention brings to the art a sub-reflector assembly 1 for a reflector antenna with improved electrical performance and significant manufacturing cost efficiencies. The sub-reflector assembly 1 according to the invention is strong, lightweight and may be repeatedly cost efficiently manufactured with a very high level of precision.

Table of Parts

1	sub-reflector assembly
2	waveguide
3	dish reflector
5	sub-reflector surface
10	RF reflective coating
15	waveguide junction portion
20	step
25	groove
30	leading cone surface
35	perturbation

[0063] Where in the foregoing description reference has been made to ratios, integers, components or modules having known equivalents then such equivalents are herein incorporated as if individually set forth.

[0064] Each of the patents and published patent applications identified in this specification are herein incorporated by reference in their entirety to the same extent as if each individual patent was fully set forth herein for all each discloses or if specifically and individually indicated to be incorporated by reference.

[0065] While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in considerable detail,

it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative apparatus, methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of applicant's general inventive concept. Further, it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope or spirit of the present invention as defined by the following claims.